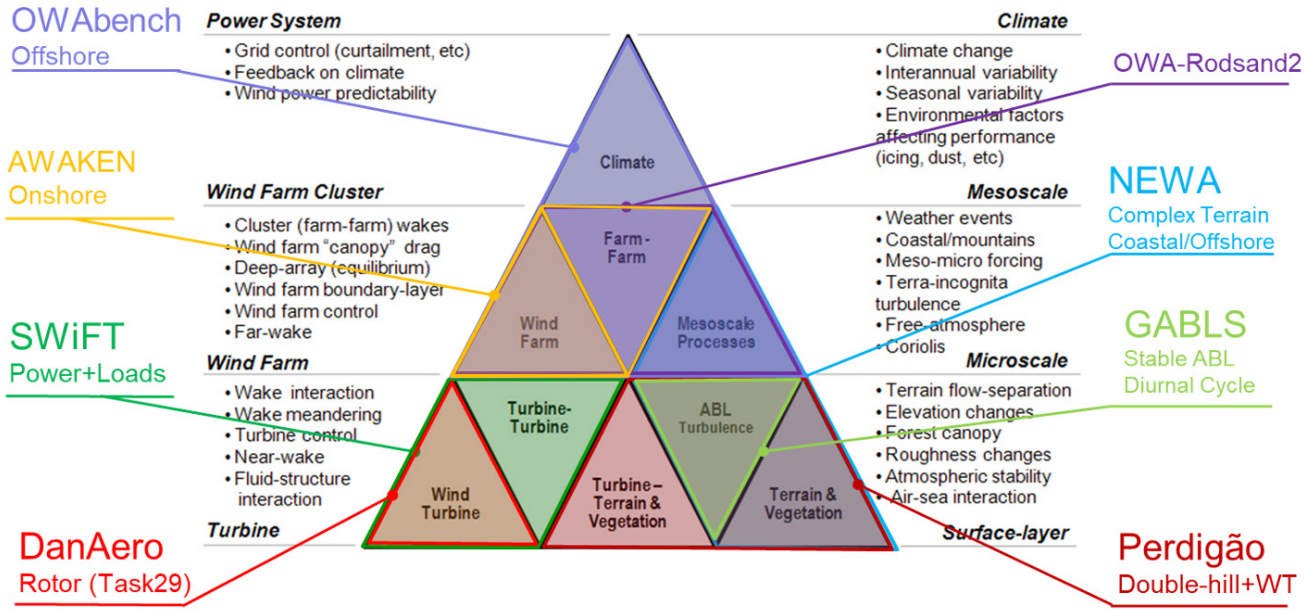


Report 2021

# Task 31

Wakebench multi-scale building-block framework and associated experiments and test sites

# WAKEBENCH: Benchmarking Wind Farm Flow Models

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**The third phase of Task 31 has gathered more than 80 organisations from 10 IEA-Wind countries in a mission to establish an international model evaluation framework for wind farm flow models.**

This phase has launched 7 benchmarks addressing wind conditions in offshore, forested and complex terrain using data from the New European Wind Atlas (NEWA) project; and 2 benchmarks addressing wake effects from the A2e-SWiFT single-wake experiment and array efficiency from 5 offshore wind farms from the Offshore Wind Accelerator (OWA) Wake Modeling Challenge. These benchmarks are progressively incorporated to the Wind Energy Model Evaluation Protocol (WEMEP), an open-source documentation project for the Wakebench model evaluation framework. With respect to previous phases (e.g. SWiFT vs Sexbierum single-wake case) we are noticing more consistent results and lower spread due to higher quality experimental data and more robust evaluation methods. Industry involvement has also improved with two

**Table 1. Countries Participating in Task 31**

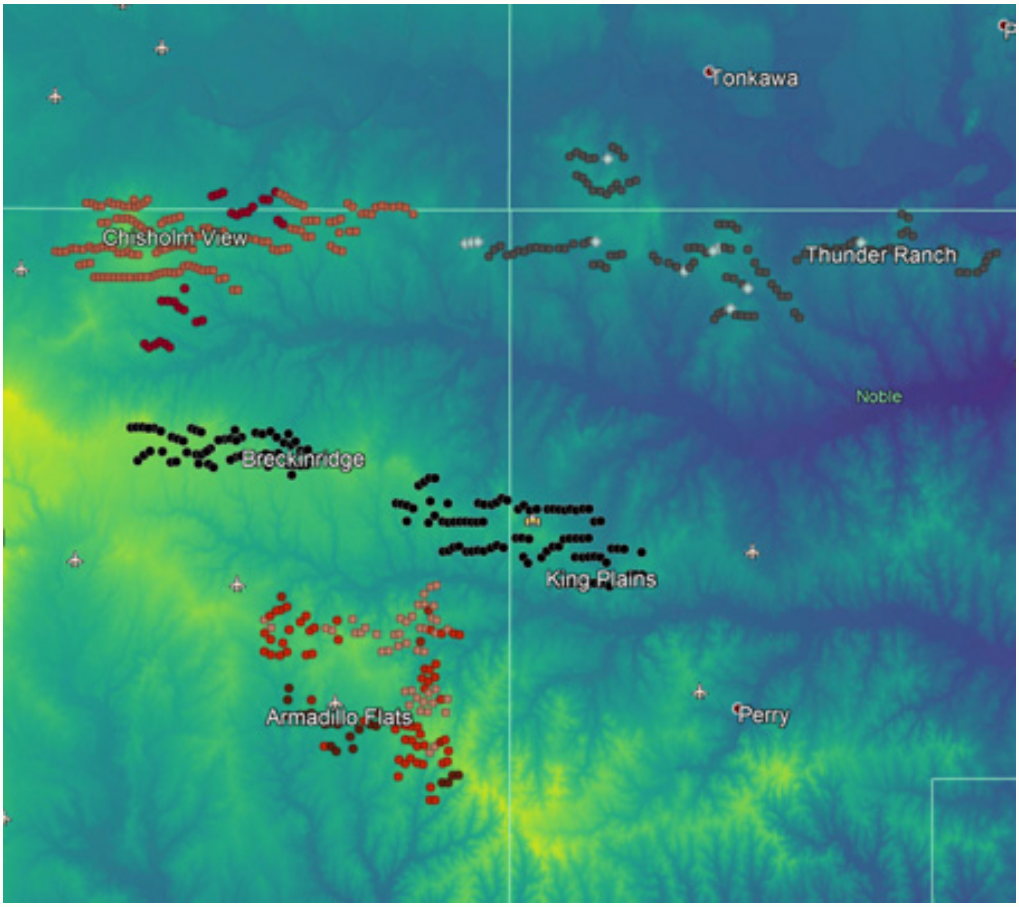
| COUNTRY | CONTRACTION PARTY | ACTIVE ORGANISATIONS |
|---|---|---|
| **China** | Chinese Wind Energy Association (CRES) | North China Electric Power University (NCEPU)<br>China Ming Yang Wind Power Group Ltd.<br>Xinjiang Goldwind Science & Technology Co. Ltd.<br>Envision Energy Co. Ltd.<br>Huaneng Clean Energy Research Institute (HCERI) |
| **Denmark** | Energistyrelsen | Technical University of Denmark (DTU)<br>EMD<br>Vestas Wind Systems A/S |
| **France** | EDR R&D<br>IFP Energies Nouvelles<br>Meteodyn | EDR R&D<br>IFP Energies Nouvelles<br>Meteodyn |
| **Germany** | Federal Ministry for Economic Affairs and Energy BMWi | Carl von Ossietzsky University of Oldenburg (ForWind)<br><br>Fraunhofer IWES<br>Enercon<br>ProPlanEn |
| **Japan** | New Energy and Industrial Technology Development Organisation (NEDO) | University of Tokyo<br>Wind Energy Institute of Tokyo (WEIT) |
| **The Netherlands** | Rijksdienst Voor Ondernemend Nederland (RVO.NL) | Technical University of Delft (TU-Delft) |
| **Spain** | National Renewable Energy Centre (CENER) | National Renewable Energy Centre (CENER)<br>Barcelona Supercomputing Centre (BSC)<br>UL |
| **Switzerland** | Bundesamt Für Energie (BFE) | Eastern Switzerland University of Applied Sciences (OST)<br>Ecóle Polytecnique Fédéral de Lausanne (EPFL) |
| **Sweden** | Uppsala University (UU) | Uppsala University Campus Gotland (UU) |
| **United States** | National Renewable Energy Laboratory (NREL) | National Renewable Energy Laboratory (NREL)<br>Sandia National Laboratories (SNL)<br>University of Colorado Boulder (CUBoulder)<br>University of Wyoming (UWYO) |

industry-led benchmarks: the OWA challenge on array efficiency prediction for 5 offshore wind farms and the Alaiz numerical site calibration case in complex terrain in support to the IEC 61400-12-4 working group. The Wakebench framework is now following the AWAKEN experiment, a large campaign led by NREL and open for international collaboration which will run until 2024. This experiment will be a core component of a new IEA Task for wind farm flow modelling and validation.

## Introduction

Current wind energy models often lead to overprediction of wind plant performance, leading to high uncertainties and significant financial losses in the wind industry. State of-the-art wind resource assessment and wind farm design techniques employ four main topics: characterisation of large-scale climatology; mesoscale meteorological processes; microscale terrain, vegetation and wind farm array effects; and wind turbine aerodynamics.

Traditionally, these topics were analysed separately, giving rise to different independent research communities (meteorologists, wind engineers, aerodynamicists). As a result, a wide variety of models have been devel-




AWAKEN

oped by each specialized group with little interaction between them [1]. The next generation of wind-energy models need an integrated approach that can produce a more comprehensive characterisation of the modelling system. The objective of IEA Wind TCP Task 31 is to develop an international verification and validation (V&V) framework that will provide sustained improvement of wind farm flow models [2]. The task leverages data from research experiments and industry alongside a formal validation strategy to provide a continuous evaluation process that improves the predictive capacity of wind farm flow models [3].

The third phase of the Task kicked-off in June 2018 and finished in May 2021 with the objective of rolling out the validation strategy built on recent field experiments from the New European Wind Atlas (NEWA) project and the U.S. Department of Energy's Atmosphere to Electrons (A2e) program. In addition, two industry-driven benchmarks were added: the Offshore Wind Accelerator Wake Modeling Challenge allowing Task participants to benchmark wind farm wake models in the prediction of array efficiency using operational data from five offshore wind farms; and, in support to the IEC 61400-12-4, the Numerical Site Calibration benchmark around the Alaiz test case in complex terrain.

## Highlight

**The AWAKEN experiment addressing wind farm validation gaps**

Overview of the area of interest for the American Wake Experiment (AWAKEN) near the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) research facility in Oklahoma. The experiment will address science questions and validation gaps related to farm-farm interaction, wind farm wakes and blockage, turbulence and atmospheric stability dependency on inflow and wake processes, etc.

## Progress and Achievements

Task 31 counts with 10 participating countries: China, Denmark, France, Germany, Japan, the Netherlands, Spain, Switzerland, Sweden, and the United States. It operates around three work packages: WP1 dealing with benchmarking of models for wind conditions, WP2 dealing with benchmarking of models for wake effects and WP3 focused on integrating these benchmarks in a model evaluation protocol that provides guidance to model developers and end-users.

The NEWA Meso-Micro Challenge for Wind Resource Assessment was launched in 2018 to determine the applicability range of meso-micro methodologies across the validation envelope of NEWA experimental sites in complex terrain such as Hornamossen forested rolling hills in Sweden [5], Rödeser Berg forested hill in Germany [6], Perdigão double-ridge in Portugal [7], and Alaiz mountain range in Spain [8]. The Ferry Lidar benchmark in Germany allows comparing mesoscale models on the prediction of wind profiles along a

ship track in the Sourthern Baltic Sea [9]. As part of a Swiss project, the Perdigão benchmark is also used to explore comparison metrics that help wind resource analysts select suitable flow models based on skill-vs-cost transfer functions [7]. The Alaiz site is used to test multi-scale flow models dealing with diurnal cycles in complex terrain [8] and steady-state models targeting flow correction factors for numerical site calibration following the guidelines from the IEC 61400-12-4 working group [10].

From the A2e program, the Scaled Wind Farm Technology (SWiFT) benchmarks provides a detailed characterisation of wake evolution and dynamics by first calibrating the inflow and then predicting the wake effects at different stability conditions [11]. Additionally, the Offshore Wind Accelerator (OWA) Wake Modelling Challenge allowed Task participants to benchmark wind farm wake models in the prediction of array efficiency using operational data from five offshore wind farms [12]. Wakebench V&V framework is documented in the Wind Energy Model Evaluation Protocol (WEMEP), a Github repository to link evaluation procedures with benchmark repositories compiled into a website using Readthedocs [13]. The framework will be further developed alongside the planning of The American Wake Experiment (AWAKEN), a large international wake observation and validation campaign carried out under the A2e program [14], [15].

## Outcomes and Significance

By adopting a framework for model evaluation, Task 31 participants can develop a model chain covering all relevant scales for wind-energy flow models through a systematic model evaluation process. This framework will also enable V&V integrated planning for wind farm performance by prioritizing experiments and simulations that can have the greatest impact on improving design tools.

Through benchmarking, researchers leverage data and share results from existing projects for wider exploitation in an international context. Industry can also use this forum to test their design tools against state-of-the-art models, provide datasets that can be used to challenge those models and end-user requirements on quality-acceptance criteria for models to meet industry standards.

## Next Steps

Task 31 finished in May 2021. A new Task is under discussion to solve outstanding challenges in the wind farm flow modelling community.

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Opening Figure: Wakebench multi-scale building-block framework and associated experiments and test sites.

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*Photo: Irfan Alijagic / Unsplash*

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